AMYGDALA $z \mapsto z^2 + c$

A Newsletter of fractals & $\mathcal{M}$ (the Mandelbrot set)
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Issue #16
April 21, 1989

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THE SLIDES (C16)

410. (Ken Philip) This is a "3 nines" midget on the spike. $-1.999774055 * 7\cdot 10^6$, E.R. =100, dwell limit = 240. Program: MandelColor 5.5; contrast CLUT.

411. (Ken Philip) This is a "4 nines" midget on the spike. $-1.99994352215 * 230\cdot 10^6$, E.R. =100, dwell limi t = 240. Program: MandelColor 5.5; contrast CLUT.

454. (Ken Philip) This is a detail of a 'submidget' lying above the -1.7115 midget on the spike. $-1.711638628 + 0.0004497876i * 5.2\cdot 10^9$, E.R. =100, dwell limi t = 240. Program: MandelColor 5.5; contrast CLUT.

801. (A.G. Davis Philip): AGDP Detail of #800: Green and purple midget surrounded by 16 lobes.

EXPIRATION AND RENEWAL

The mailing label on the envelope you received this copy of Amygdala in has a small box in the lower right hand corner. The legends in the box indicate when your subscription to the newsletter and (if you get it) slide supplement expire. "N23" means newsletter #23 is the last one you'll receive; "N16" means THIS one is your last!

If you get the slide supplement, "C23" means slide set 23 (the one accompanying newsletter #23) is your last; "C16" means this one is your last.

For that considerable number of you (223) who have "C16": if you want to continue to receive the slide supplement please renew promptly to avoid missing slide set C17. $19.60 will get you six slide sets: C17 through C22; $32.00 will get you ten: C17 through C26. (The $27.00 quoted in Amy #15 was an error.)

HIDDEN LINE REMOVAL — CORRECTION

—*Ken Philip*

In AMY #13, you said at the end of the first page that my hidden-line suppression method was to plot from the back to the front of the image. That's fine as far as it goes — but you left out the *important* step, which is to erase from just under the pixel being plotted to the bottom of the screen. It's the combination of the erasing *and* the back-to-front plotting that does the hidden line suppression.

MOTHER-OF-MILLIONS

Struck by the shape of the "Mandelbrot Plant", Reinald Eis wrote the following beautifully illustrated article about it. My wife Beverly has these plants growing around the house; they are called *Mother-of-Millions* or *Live Forever.* She writes:

> If the plant grows very tall and is then moved it will fall and reroot where it touches earth; it will fall because it will previously have been resting against a wall. The plant propagates however it can — it buds along the leaves, making replicas of itself which fall to any available soil. It flowers by making a purple hanging cluster. If you leave the flower on the plant after it dies, new flowers and then buds will spring from the dead clusters. Many plants in one container tend to stay small; one alone will grow very large.

Living Fractals

Abstract:
'Kalanchoe daigremontiana' is a plant with leaves that are reminiscent of the Mandelbrot Set.

Paradoxical

There is no denying that, in principle, computers are nothing but stupid number-crunchers, inanimate and alien to nature. And yet exactly these machines are contributing so much to our understanding of nature: Deterministic chaos and fractalness had gone unnoticed until the advent of the electronic calculator.

I think computer-generated pictures of the Mandelbrot Set are perfect examples of a similar paradox: Time and again it amazes me that a stupid machine executing a tedious iterative algorithm should be capable of producing such a wealth of quasi-organic structure.

A New Perspective

Exploring fractal sets can be an enlightening experience: A new way of looking at the 'real world' presents itself, and all of a sudden it becomes evident: *All Things are Fractal*.

You inevitably develop 'An Eye for Fractals', as Michael McGuire calls it in 'The Science of Fractal Images'. Perhaps some of the most intriguing examples of fractalness can be found in the plant kingdom.

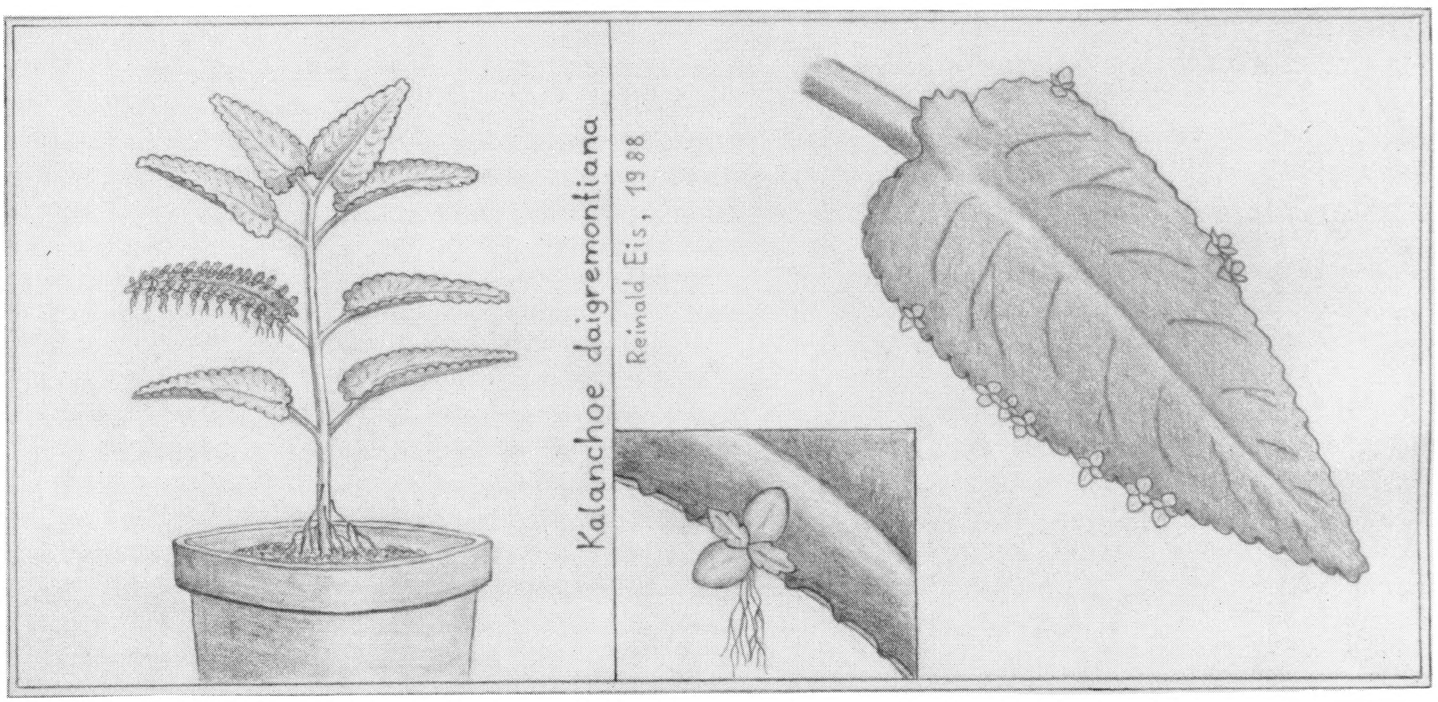
To tell the truth, until recently I used to be quite ignorant of this aspect, as I did not care much about greenery. But I have experienced a conversion, so to speak.

Fractal Flora

Some friends of mine are passionate amateur floriculturists. One day, while visiting them, I was expected to admire their rock-garden and their vast collection of potted plants. As may be understood, this prospect failed to kindle much enthusiasm in me. Muttering a few polite phrases now and then I resigned myself to fate. My vanishing interest had just sunk below zero level when I was thunderstruck by the sight of a truly fantastic plant.

The M-Set comes Alive!

In complete wonder I gazed at the leaves of this plant. Never before had I seen such an impressive demonstration of self-similarity: To each leaf numerous miniature replicas of the plant were attached all along the leaf margin. A closer examination revealed the fact that sometimes even a third generation was already developing on the folioles of the young plants.



The whole affair reminded me so strongly of the Mandelbrot Set and its peripheral excrescences that I considered the name 'Mandelbrot Plant' to be perfectly appropriate.

More Questions than Answers

Of course I instantly asked my friends what kind of plant this was. Although they are very knowledgeable about their hobby, in this case all they could tell me was that they had found the plant in a greenhouse of the Heidelberg Institute of Botany. Naturally they were puzzled by my sudden interest. So I began to expound fractals and the Mandelbrot Set to them. On my next visit I brought some pictures, and they, too, perceived the similarity.
As I was eager to find out more about this remarkable plant I soon went to the Botanical Institute. However my inquiry there was to yield a rather disappointing result: The M-Plant was neither a novel species nor quite as unique as I had deemed it.

Ye shall know Them by Their Leaves.

Actually this marvel of a plant is just a weed! However, as a compensation it boasts a number of peculiarities. For one thing, there is its unusual way of multiplication: Leaves functioning as reproductive organs are a rare occurrence in nature. Another one of its oddities calls for some further explanation: The M-Plant reproduces mainly by way of parthenogenesis, i.e. non-sexually. So far this is really nothing special. Parthenogenesis causes a plant and its offshoots to be clones. The remarkable thing about M-Plants is that, in spite of their genetical identity, they do not necessarily look the same. Leaves of two individuals may differ very much from each other in form, depending on environmental conditions during growth: The length of regular exposure to daylight determines whether they will become thick-leaved and small, having a straight margin (when exposed for 8 h), or larger, more lanceolate and crenate (16 h exposure).
Interestingly the M-Plant also has a rather exceptional metabolism, which is typical of the family Crassulaceae, but different from all other plants. For this reason it serves as a popular experimental object to undergraduate students of botany.

The plant is a succulent, native to warm temperate regions. It will not survive outdoors in harsher climates, e.g. in most parts of Germany.
Having satisfied my curiosity for this time I finally asked for some literary references.

Still More Botanical Jargon

On the very next day I proceeded to the university library in order to complete my quest for knowledge.

This, for instance, is what I found in a botanical encyclopaedia: [1])

Bryophyllum Salisb.

Perennials with opposite leaves. Flowers 4-merous, in cymes; corolla tubular, with short lobes; stamens 8, inserted near the base of the corolla:

1. B. pinnatum (...) (B. calycinum Salisb.). Stems 1 m or more, erect, woody at the base. Leaves petiolate, simple, ternate or pinnate; leaflets up to 10 cm, ovate, crenate, often with young plants arising on the margins between the crenations. Flowers pendent, in compound cymes. Calyx 3 cm, tubular, with short, triangular lobes; corolla similar but 4-5 cm, and with longer, more acute lobes; both pale green mottled with red. Follicles erect. Widely cultivated, and naturalized in many tropical and subtropical countries, also in Açores. (Madagascar.)

An Excursion to History

The genus 'Bryophyllum' has been known to science for a long time, and all species have been researched in depth.
For the first time these plants were mentioned in the works of Richard Anthony Salisbury (1761-1829), one of the most distinguished botanists of this era.

[1]) 'Flora Europaea', Volume 1: Lycopodiaceae to Platanaceae, edited by T.G. Tutin, V.H. Heywood et al, Cambridge University Press 1964, p.351

One species was also studied by Freiherr Johann Wolfgang von Goethe (1749-1832), a universal genius, who became famous for his poetry, but was a respected scientist and lawyer, as well. The plant caught his attention because of its striking reproductive mechanism.

The Name Game

In literature two generic names can be found:
1) 'Bryophyllum' is obsolete now, though I find this term more descriptive: In a loose translation it means 'leaves of lush growth'.
2) 'Kalanchoe' is today's nomenclatural name.
There are several species and interspecific hybrids.
The species Goethe had in hand goes by a popular name sounding a bit poetic: 'Air- (or life-) plant'. In the vernacular of botany it is called 'B. calycinum' or 'K. pinnata' (see above).
The plant that I stumbled upon belongs to the species 'B. (or K.) daigremontiana' and is commonly named 'flopper'.
In some species (as in Goethe's) the brood buds do not develop further until the mother leaf has fallen off.
In others (as in mine) the buds grow to become small plants while the mother leaves remain on the plant. Because the plantlets are fully developed, including primordial roots, they can take root as soon as they fall to the ground.
Similar brood buds can be found in some ferns (e.g. Asplenium rhizophyllum, W. Virginia), but they look only half as spectacular.

Grow Your Own Mandelbrot-Plant!

Above illustrations cannot convey the fascination of the living plant. One needs to see it *in natura* to believe.
It is surprising how little popular Bryophyllum still is far and wide, as the plant looks interesting and is easily cultivated.
So why not grow your own M-Plant - it's fun! Simply get a scion, plant it, and watch it proliferate.
Your M-Plant will require hardly any effort: It will thrive on simple garden mould, it only needs moderate amounts of water, and prefers a warm place in the shade.
♦

AUTHORS

Reinald Eis was born in 1958 in a small town in West Germany. He was vocationally educated as a commercial clerk, but found the job uninspiring. At present he is a student of chemistry at the University of Heidelberg. He became interested in computers some five years ago, and fractal topics have fascinated him since he read the original article in Scientific American in 1985.

—*Rollo Silver*

Joe Short wrote, "Just got issue #13. Enjoyed the bio on Loyless. How about one on *Rollo* in the future!!" So, here ya go...

Asked by Martin Gardner for a bio, I wrote him that I am

> ...an ontological engineer who lives and works in the mountains of Northern New Mexico. Deprived of the company of his peers and half-crazed by isolation, he started *Amygdala* in self-defense in 1986.

To amplify a bit, I got a B.S. in Math from Harvard (class of 1949). One of my three roommates in my Junior year there was Marvin Minsky.

I started working with computers at Lincoln Lab in 1954. After that, I worked for Bolt, Beranek & Newman in Cambridge, Mass (where Ed Fredkin was working at the time), then for the Mitre Corp.

I left Mitre and the East with my family in 1969 to come out to the Southwest. We settled temporarily in Taos ... and have never left.

We spent 3 intense years building a round (40 ft diameter) yurt-like house out of homemade soil cement bricks, where we (wife Beverly, daughter Liyana, now 16, self) have lived ever since.

For many years the cash flow came from computer consulting forays back East and to the West coast. That source has since dried up, and we exist on the modest revenues produced by weaving (Bev) and desktop publishing (Rollo).

After several fruitless and frustrating forays into software development and software salesmanship, I decided that it's better for me to do what I like rather than waste my time and energy on enterprises yielding neither fun nor money.

So at this point I'm concentrating on two things: fractals & Amygdala on the one hand, and development of the Modcap programming language and system (with Mark Wells) on the other hand.

Mark has been developing Madcap/Modcap for 15 years or so; I caught the bug in 1978, and have been helping him with it ever since. Someday it'll be "out" to the point where you programmers can catch a glimpse of it — lucky you! It's beautiful!

TUTORIAL — THE BINOMIAL EQUATION

—RS

(Continued from Amy 15.3)

In this installment we are going to look closely at calculating the nth power a^n of a complex number a.

Let's start by expressing a in polar form. From (14.9)[1]:

$$a = re^{i\theta} = r(\cos\theta + i\sin\theta) \qquad (16.1)$$

The tutorial in Amy #14 indicated the following:

(1) Since the modulus of a product is the product of the moduli, $|z_1 z_2| = |z_1||z_2|$, it follows that the modulus of an nth power (integer $n > 0$) is the nth power of the modulus: $|z^n| = |z|^n$.

(2) *The argument of a product is equal to the sum of the arguments of its factors,* hence:
$|\arg z^n| = n \arg z.$

Applied to (16.1) these give us, for $n > 0$:

$$a^n = r^n e^{in\theta} = r^n(\cos n\theta + i\sin n\theta) \qquad (16.2)$$

Since $z^0 = 1$, $\cos 0 = 1$, and $\sin 0 = 0$, (16.2) is valid for $n = 0$ as well.

For $n = -1$, we have $a^{-1} = r^{-1}(\cos(-1)\theta + i\sin(-1)\theta)]$. A bit of algebra will show that $Aa = 1$, where

$$A = r^{-1}(\cos(-1)\theta + i\sin(-1)\theta).$$

This can easily be extended to all negative integers, since $a^{-n} = (a^{-1})^n$; so (16.2) is valid for all integers.

For the particular case where $r = 1$, (16.1) and (16.2) taken together give *de Moivre's formula:*

$$\cos n\theta + i\sin n\theta = (\cos\theta + i\sin\theta)^n \qquad (16.3)$$

This formula gives us a way to express $\cos n\theta$ and $\sin n\theta$ in terms of $\cos\theta$ and $\sin\theta$, if we recall the binomial theorem:

$$(a+b)^n = \sum_{m=0}^{n} \binom{n}{m} a^m b^{n-m} \qquad (16.4)$$

where

$$\binom{n}{m} = \frac{n!}{m!(n-m)!} \qquad (16.5)$$

Thus, for example

$$\cos 3\theta + i\sin 3\theta = (\cos\theta + i\sin\theta)^3 =$$
$$\cos^3\theta - 3\cos\theta\sin^2\theta + i(3\cos^2\theta\sin\theta - \sin^3\theta),$$

so

$$\cos 3\theta = \cos^3\theta - 3\cos\theta\sin^2\theta$$

and

$$\sin 3\theta = 3\cos^2\theta\sin\theta - \sin^3\theta$$

We can find the nth root of a complex number $a \neq 0$ by solving the equation

$$z^n = a \qquad (16.6)$$

Let $a = r(\cos\theta + i\sin\theta)$ and $z = \rho(\cos\varphi + i\sin\varphi)$. Then (16.6) becomes

$$\rho^n(\cos n\varphi + i\sin n\varphi) = r(\cos\theta + i\sin\theta) \qquad (16.7)$$

which is satisfied by $\rho^n = r$ and $n\varphi = \theta$. Therefore we have

$$z = \sqrt[n]{r}\left(\cos\frac{\theta}{n} + i\sin\frac{\theta}{n}\right) \qquad (16.8)$$

where $\sqrt[n]{r}$ is the positive nth root of the positive number r.

But (16.8) is not the only solution of (16.6), which has n different solutions. (16.7) is satisfied not only by $n\varphi = \theta$, but by $n\varphi = \theta + 2k\pi$, for all integers k. However, only the values $k = 0, 1, \ldots, n-1$ give different values of z. The complete solution of the equation (16.6) is therefore:

$$z = \sqrt[n]{r}\left[\cos\left(\frac{\theta}{n} + k\frac{2\pi}{n}\right) + i\sin\left(\frac{\theta}{n} + k\frac{2\pi}{n}\right)\right], \qquad (16.9)$$

for $k = 0, 1, \ldots, n-1$

Any non-zero complex number has n nth roots. They all have the same modulus, and their arguments are equally spaced.

Geometrically, the nth roots form the vertices of a regular polygon with n sides.

The case $a = 1$ is particularly important. The roots of the equation $z^n = 1$ are called the nth roots of unity, and if we define

$$\omega = \cos\frac{2\pi}{n} + i\sin\frac{2\pi}{n} \qquad (16.10)$$

the nth roots of unity can be expressed as $1, \omega, \omega^2, \cdots, \omega^{n-1}$. It is clear that if $\sqrt[n]{a}$ denotes any nth root of a, then all of the nth roots of a can be expressed as $\sqrt[n]{a}\,\omega^k$, $k = 0, 1, \cdots, n-1$.

EXERCISES

1. Express $\cos 4\theta$ and $\cos 5\theta$ in terms of $\cos\theta$ and $\sin\theta$.
2. Simplify $1 + \cos\theta + \cos 2\theta + \ldots + \cos n\theta$ and $1 + \sin\theta + \sin 2\theta + \ldots + \sin n\theta$.
3. Express the fifth and tenth roots of unity in algebraic form.
4. If ω is defined by (16.10), prove that
$$1 + \omega^h + \omega^{2h} + \cdots + \omega^{(n-1)h} = 0$$
for any integer h which is not a multiple of n.
5. What is the value of
$$1 - \omega^h + \omega^{2h} - \cdots + (-1)^{n-1}\omega^{(n-1)h}\ ?$$

[1] (14.9) refers to equation 9 from the tutorial in Amygdala #14 (pages 4-5).

THE GAME OF FRACTAL IMAGES

—Ken Philip

A copy of the Macintosh II color Mandelbrot/Julia program "The Game of Fractal Images [Part 1: The Mandelbrot Set]", published by Springer Verlag, has been received for review. This disk forms a companion to the book "The Science of Fractal Images", and utilizes several algorithms from that work.

Major features are:

◆ Computes the Mandelbrot Set by Escape Time (the 'usual' method) and by Distance Estimator (a superfast algo-

rithm described in Appendix D of TSOFI). The Escape Time method uses a grid scan rather than a raster scan, which brings up a rough view of the image early in the procedure and refines it with each successive pass — without re-plotting any pixels.

- ◆ Computes Julia Set images by both the above methods, and also uses Inverse Iteration (described in TSOFI, and related to Barnsley's Iterated Function Systems) to compute fast B&W images.
- ◆ Saves images to disk. Runs in background under MultiFinder (but grabs a full megabyte for itself.) A powerful Color Editor lets you control the appearance of images. The initial steps in iteration tracks may be displayed over an image of the Mandelbrot Set — a fascinating feature!

A full review will follow when this program has been evaluated...

CHAOTIC BOOKS (AND OTHERS)

This column, begun in the last issue, gives short notices of books which are available from Amygdala and may be of interest to Amygdala readers.

Global Bifurcations and Chaos — Analytical Methods

— Stephen Wiggins

1. Introduction: Background for Ordinary Differential Equations and Dynamical Systems.
2. Chaos: Its Descriptions and Conditions for Existence.
3. Homoclinic and Heteroclinic Motions.
4. Global Perturbation Methods for Detecting Chaotic Dynamics.

- ◆ The study of chaotic phenomena in deterministic nonlinear dynamical systems has attracted much attention over the last fifteen years. For the applied scientist, this study poses three fundamental questions. First, and most simply, what is meant by the term "chaos"? Second, by what mechanisms does chaos occur, and third, how can one predict when it will occur in a specific dynamical system?

- ◆ We will describe a two dimensional map possessing an invariant set having a delightfully complicated structure. Our map is a simplified version of a map first studied by Smale and, due to the shape of the image of the domain of the map, is called a *Smale horseshoe*.

Dynamical Systems I

—D.V. Anosov and V.I. Arnold (Eds)

I. Ordinary Differential Equations

— V.I. Arnold and Yu. S. Il'yashenko

1. Basic Concepts.
2. Differential Equations on Surfaces.
3. Singular Points of Differential Equations in Higher Dimensional Real Phase Space.
4. Singular Points of Differential Equations in Higher Dimensional Complex Phase Space.
5. Singular Points of Vector Fields in the Real and Complex Planes.
6. Cycles.
7. Analytic Theory of Differential Equations.

The Mathematical Structure of Raster Graphics

— Eugene L. Fiume

From the publisher's blurb:

AUDIENCE: Researchers and graduate students interested in the theoretical bases of computer graphics.

GENERAL DESCRIPTION: This book presents a mathematical characterization of the structure of raster graphics — a popular and diverse form of computer graphics — while focusing on 3-dimensional raster graphics. The book is of interest to anyone with a basic computer graphics background as well as well as researchers involved in the formal specification of graphics systems, in that it provides a mathematical basis for the formal specification of graphic primitives and operations on them. It is also suitable for a graduate-level topics course in image synthesis.

FEATURES AND BENEFITS:

- ◆ First book to present a mathematical treatment of rendering, visibility, and bit-mapped graphics from a computer-graphics perspective.
- ◆ Suggests interesting open problems.
- ◆ Yields useful theoretical and practical insights into the basic properties shared by most graphics systems.
- ◆ Efficient practical approximations are derived from their ideal specifications, and their accuracy is assessed.

CONTENTS:

Motivation and Overview. Scene Specification. Visibility. Rendering. Bit-Mapped Graphics. Illumination Models. The Complexity of Abstract Ray Tracing. The Last Word. References. Index.

FAST MANDELBROT INNER LOOP FOR BASIC PROGRAMS

— Martin Combs

After reading MACINTOSH MANDELBROT PROGRAMS by Ken Philip in issue #11 of Amygdala it is apparent that Macintosh owners have the same wide choice of Mandelbrot programs as do Amiga owners, with the same reasons for dissatisfaction. Each programs satisfies its own author, but no program satisfies everybody. Most of your readers could probably write a program in BASIC which would be individually tailored to fit their needs exactly, but everyone knows that BASIC is excruciatingly slow. Actually, BASIC isn't too slow to do a pretty good job with graphics, it is just that the $z \mapsto z^2+c$ algorithm takes too much time to do any meaningful number of iterations.

My solution was to put the algorithm into a machine language routine and call it from BASIC. The routine consists of 250 bytes which I read in from DATA statements and POKE into the higher elements of a long integer array. The lower elements of the same array are used to pass parameters to and from the routine. Since the routine stands alone, that is, it makes no calls to other routines, it should be readily usable by any other 68000 based machine. As long as the other machine speaks a version of BASIC reasonably similar to Microsoft's version, modification of the BASIC portion of the program should be no problem. The machine language portion requires no change to fit any 68000 machine, as far as I know.

The high speed and small size of the machine language routine is due to the fact that it is all integer and that it is tightly tailored to the algorithm, having no wasteful general purpose subroutines. Since there is no need to deal with numerical values greater than 4 (the square of the maximum distance of a point in the Mandelbrot set from the origin of the coordinate system) all numerical quantities can be scaled up by a factor of 2^{28} and still stay within the limits of long integer arithmetic. This gives precision approximately the same as single-precision floating point, but should be considerably faster, at least for those of us who are unfortunate enough to lack a 68881 chip and extra RAM. Incidentally, I have also written a routine which scales up by a factor of 2^{60}, about equivalent to double-precision floating point. It runs at about one third the speed of the other.

The output of the machine language routine for each pixel is the number of iterations required to drive the point to a distance of 2 from the origin of the coordinate system, providing that the number of iterations is less than some specified maximum. If the maximum number of iterations is reached, the output is the sum of the specified maximum iterations and an appropriately scaled number representative of the distance of the iterated point from the origin at the time that the last iteration was completed. An output greater than the specified maximum iteration can simply be used as an indication that the pixel is in the Mandelbrot set, or it can be used to give some idea of the structure of the interior.

The BASIC program plots the Mandelbrot set with the option of saving to file the output for every pixel. This output file is used in conjunction with a plotting program to plot the set as often as needed, much more rapidly than it was generated, with varying color combinations and various choices of breakpoints between regions of the set. The possibilities are endless. The machine language program also handles Julia sets, for those who have wondered what they were.\ The algorithm is the same for with Julia and Mandelbrot sets, with different inputs.

The plotting and generating programs were written with numerous contributions and considerable encouragement from Anselm Wachtel, as well as some ideas of Zoltan Szepesi, but the machine language is entirely my own.

I would be willing to provide these programs to those of your readers interested, including an assembly language listing of the machine code. The simplest way would be for me to send a disk, which would cost say $4. Those of your readers without access to an Amiga could obtain a listing.

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LETTERS

From Michael Freeman (May 1, 1988):

A topic I'm interested in is getting *really* high resolution pictures of Mandelbrot and Julia sets. I wonder if any of your readers know of anything produced to more than 8192 x 8192 pixels? I was involved in making such a picture, of a region similar to Map 36 in TBF, calculated to a dwell limit of 1024. The calculation was done on a mainframe, then moved to a FIRE 240 film recorder which produced an 8 inch square transparency. The picture is not now available, but may one day be sold as a poster by Advanced Satellite Productions of Vancouver. One might ask if there is any point to calculating so many pixels; I think the result indicates that there is. All you need to blow up a region of interest is a magnifying glass!

On a somewhat more approachable note: high resolution can be obtained on printers, too. Many people are aware that laser printers can make 300 dots per inch; not so many may know that even a modest dot matrix printer can do almost as well: I have a Roland 1212 (sold in the US as Panasonic), and I believe what I am describing applies to Epson as well.

First a calculation is done of a region of interest, 1920 x 2160 pixels. The results fit into 518,400 bytes (stored 1 pixel/bit) which is stored in one or two files. To print, the 1920

pixel horizontal line is done as quadruple density graphics. On my printer, I cannot print adjacent pixels at this density, so I make two passes. To get the 2160 vertical, the top 8 pins of the print head print 8 rows, separated by 1/72 inch. Then by doing a vertical shift of 1/216 inch, I get another 8 rows, and finally another 8 with a second shift.

Altogether, the print head must make 6 passes to print 24 full rows. These take up 1/9 inch, or 216 pixel rows per inch. It takes about 3 hours to print, once the data is in files. Of course, the calculation could take much longer. I suggest using a friction feed to keep the paper fixed firmly.

Michael Freeman / 4777 Hoskins Road / North Vancouver, B.C. V7K 2R3 / CANADA

"FRACTAL REPORT"

FRACTAL REPORT is a new publication, published by Reeves Telecommunications Laboratories Ltd., / West Towan House / Porthtowan / Cornwall TR4 8AX / United Kingdom.

Issue 0 runs to 24 pages:

Introduction	Karen Griffin
Editorial	John de Rivaz
From Star Trek to the Slipperstone Ridge	Mark Datko
Random Generation of Fractals	John Sharp
Enhancing Mandelbrot Fractals	Larry Cobb
Mandelbrot Generators on the M'intosh II	Mark Datko
The Larry Cobb Prize	Larry Cobb
Fractals, Maths & Graphics	Simon Goodwin
Pleasing Mandelbrot Images	David Stevenson

A subscription is £10 UK, £12 Europe, £13 elsewhere. Subscriptions are backdated to volume start. Free subscriptions to future volumes (six issues) for contributors.

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CIRCULATION

As of April 21, 1989, Amygdala has 639 paid-up subscribers , 263 of whom have the supplemental color slide subscription.